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Whole Lake Additions in the Experimental Lakes Area, 1986-1989

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ABSTRACT

Cruikshank, D.R. 1991. Whole lake additions in the Experimental Lakes Area, 1986-1989. Can. Data Rep. Fish. Aquat. Sci. 816: iv + 18 p.

Acidification of three lake basins continued from 1986 to 1989. Sulfuric acid was added to Lakes 223 and 302S while nitric and hydrochloric acids were added to Lake 302N. Additions of sulfuric acid were halted to Lake 114. Nitrogen and phosphorus were added to Lake 227 in continuation of a 20-year eutrophication experiment. Cadmium chloride and cadmium^{109} were added to Lake 382 in 1987, 1988 and 1989. Radionuclides were added to the hypolimnetic waters of Lake 226. Two lake enclosure experiments were started; nutrient additions were made to enclosures in Lake 227 and organic chemicals were added to enclosures in Lake 375.

Key words: acidification; fertilization; trace metals; whole-lake manipulations.

RÉSUMÉ

Cruikshank, D.R. 1991. Whole lake additions in the Experimental Lakes Area, 1986-1989. Can. Data Rep. Fish. Aquat. Sci. 816: iv + 18 p.

On a poursuivi l'acidification de trois bassins entre 1986 et 1989. De l'acide sulfurique a été ajouté dans les lacs 223 et 302S. De l'acide nitrique et de l'acide chlorhydrique ont été ajoutés dans le lac 302N. On a interrompu l'addition d'acide sulfurique dans le lac 114. Dans le cadre d'un programme expérimental d'eutrophisation étalé sur vingt ans, on a ajouté de l'azote et du phosphore dans le lac 227. Du chlorure de cadmium et du cadmium^{109} ont été ajoutés dans le lac 382 en 1987, en 1988 et en 1989. Des radionucléides ont été ajoutés dans les eaux hypolimniques du lac 226. On a amorcé des expériences à l'intérieur des limites de deux lacs: des éléments nutritifs ont été ajoutés dans le cas du lac 227 et des produits chimiques organiques ont été ajoutés dans de cas du lac 375.

Mots-clés: acidification; fertilisation; métaux traces; expériences portant sur l'ensemble d'un lac.

INTRODUCTION

This report is the third in a series of reports on whole lake additions at the Experimental Lakes Area (ELA). For data on additions from 1969-1983 inclusive see Cruikshank (1984). For data on additions made during 1984 and 1985 see Cruikshank (1986). Summary data on additions from past years are included in the tables with the new data from 1986-1989. Equipment and methodology remain unchanged and were described in the first report.

The addition ratios of carbon, nitrogen and phosphorus to L227 remain unchanged from past years (Table 1). In June 1988, six 5 m diameter polyethylene tubes (limnocorrals) were installed in L227. Various amounts and ratios of nutrients and micronutrients were added to the tubes to study the effect micronutrients had on algal production (Table 2).

In 1987, a whole lake addition of cadmium began on L382 (Table 3a). The experiment is designed to test the adequacy of the Canadian Water Quality Guideline of 0.2 ug Cd L^{-1}. Cadmium was added in two forms. The majority of the cadmium was in the form of cadmium chloride. A radiotracer, ^{109}Cd was added to follow the fate, accumulation and pathways of uptake of the Cd added to the lake.

In 1989, a mixture of furans with a ^{3}H radiotracer was added to each of four lake enclosures in L375 (Table 3b). The fate of the furans was followed in sediments and aquatic organisms placed in the tubes. This experiment was conducted on a trial basis as a precursor to a whole-lake experiment involving organic chemicals.

The acidification experiment on L114 was terminated after the monthly addition in October, 1986 (Table 4). This experiment involved a monthly addition of sulfuric acid to L114 which was equivalent to the amount of $[H^+]$ received in rainfall, in the Muskoka region of Ontario, in one month.

L225 is a small (3.99 ha) shallow (<1.75 m deep) humic lake (pH = 5.15). In July 1987, two additions of hydrochloric acid (total of 70 litres) were made. This experiment was to study the effects of further acidification of an already acidic system on light transparency and any changes in zooplankton genetics.

The recovery phase of the long-term acidification experiment of L223 continued. The target pH for 1986 and 1987 was 5.4. In 1988-1989 the lake was allowed to recover to a target pH of 5.8 (Table 5).

L302 is a double-basin lake divided by a polyethylene curtain wall into L302N and L302S. In 1986, the nitric acid additions to L302N ended on October 21. This concluded a five-year experiment comparing the effects of nitric vs sulfuric acids on lake chemistry and aquatic ecosystems. Beginning in June 1987, additions of hydrochloric acid to L302N were made. These additions were continued in 1988 and 1989 (Table 6). The plan was to keep L302N at a pH near but less than 5.4 in 1988. This target pH was selected for a future experiment on the nitrogen cycle. In 1989, the target pH for L302N was 5.0.

Sulfuric acid additions to L302S continued with a target pH of 5.0 and 4.75 for 1986 and 1987 respectively. The target pH in 1988 and 1989 was 4.5 (Table 7). Additions to reduce the pH to below pH 5.0 in 1987 and 1988 were continued to document the effects of low pH on aquatic organisms.

Atomic Energy of Canada added 3 radiotracers consisting of 10 curies ^{3}H, 125 mCi ^{60}Co and 125 mCi ^{134}Cs to the waters of the hypolimnion of L226. AECL were following the movement of the tracers through the lake system.

METHODS

Acid additions to L114, L225, L223, and L302 were made using the "Prop-tube mix" method. Nutrient additions to L227 were made using the "barrel method" (Cruikshank 1984). Micronutrients were added to each tube (limnocorral) in L227 from a container that contained the previously mixed ratios of nutrients for each respective tube. Each nutrient solution was trickled into the tube by sliding the boat around the tube circumference and adding a little solution every metre. The entire tube was then mixed by stirring using a paddle.

In 1987, cadmium was added twice a week to the epilimnion of L382. A container with an outlet consisting of Tygon tubing with a syringe attached. The radiotracer cadmium was first added to the container followed by the cadmium chloride dissolved in water. The solution then slowly dripped into the lake over a period of two days. The delivery apparatus was attached to a buoy in the center of the lake. The delivery system was modified in 1988 using a small battery operated pump to provide a continuous flow during the ice-free season.

CHEMICAL SOURCES

The sulfuric, hydrochloric and phosphoric acids and the sodium nitrate were purchased from two local Winnipeg firms. The sulfuric acid came in 10 litre (18 kg) plastic carboys, the hydrochloric acid in 20 litre (22 kg) carboys and the phosphoric acid in 34 kg cubitainers. Costs vary from year-to-year but the unit prices for sulfuric and phosphoric acid in 1989 were 21 dollars and 74 dollars respectively. The hydrochloric acid was priced at 11 dollars per carboy in 1987. The sodium nitrate was purchased in 25 kg bags for 16 dollars a bag in 1989. The calcium chloride was purchased in 1989 for 339 dollars for 2.5 kg. The cadmium radiotracer was leftover from previous work.

New suppliers were found for the sulfuric acid in 1986. The sulfuric acid is 93.2% pure with a specific gravity of 1.835. The sulfuric acid used prior to 1986 was 93.29% pure with a specific gravity of 1.81. The phosphoric acid is 85% pure with a specific gravity of 1.686. The hydrochloric acid was 31.45% pure with a specific gravity of 1.10.

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REFERENCES

CRUIKSHANK, D.R. 1984. Whole lake chemical additions in the Experimental Lakes Area, 1969-1983. Can. Data Rep. Fish. Aquat. Sci. 449: iv + 23 p.

CRUIKSHANK, D.R. 1986. Whole lake chemical additions in the Experimental Lakes Area, 1984-1985. Can. Data Rep. Fish. Aquat. Sci. 580: iv + 10 p.

Table 1. L227 nutrient additions.

Year	Date	Sodium Nitrate				Phosphoric acid				
		kg/wk	Total kg	kg N per wk	Total kg N	Litres per wk	Total litres	Total kg	kg P per wk	Total kg P
1986	May 06 - Sep 16 (20 additions)	34.0	680.4	5.61	112.2	2.5	50.0	85.0	1.14	22.83
1987	May 05 - Sep 15 (20 additions)	34.0	680.4	5.61	112.2	2.5	50.0	85.0	1.14	22.83
1988	May 10 - Sep 20 (20 additions)	34.0	680.4	5.61	112.2	2.5	50.0	85.0	1.14	22.83
1989	May 16 - Sep 26 (20 additions)	34.0	680.4	5.61	112.2	2.5	50.0	85.0	1.14	22.83

N.B. All additions to L227 from 1975-1988 inclusive were made in the N:P ratio of approximately 5:1. Additions from 1969-1974 were made in a 13:1 ratio of N:P. The phosphoric acid has a S.G.= 1.686.

Table 2. L227 limnocorral additions 1988.

Limnocorral #	Treatment 1988 (June 3 - Aug 23)	Treatment 1989 (May 31 - Aug 29)
1	N, P, trace metals	NO TREATMENT
2	N, P	N, P
3	EDTA, N, P	NO TREATMENT
4	N, P	P
5	high P	N, P
6	N, P, trace metals	P

Treatment sources as follows:

Treatment	Quantity (wt. chemical per week to each corral)
N	13.53 g $NaNO_3$
P	1.0 mL H_3PO_4
EDTA	8.74 g
Trace metals - EDTA	8.74 g
- $FeCl_3 \cdot 6H_2O$	6.30 g
- H_3BO_3	2.00 g
- $MnCl_2 \cdot 4H_2O$	0.36 g
- $Na_2MoO_4 \cdot 2H_2O$	0.012 g
- $ZnSO_4 \cdot 7H_2O$	0.044 g
- $CaCl_2 \cdot 6H_2O$	0.02 g
- $CuSO_4 \cdot 5H_2O$	0.02 g

On August 31, 1988, 200 g of Rotenone was added to each limnocorral.

Table 3a. L382 cadmium additions.

Year	Grams Cd added	^{109}Cd mCi added	Target Epi [Conc] ng Cd/L	Mean Epi [Conc] ng Cd/L
1987	900	89	100	83
1988	640	62	100	51
1989	686	68	120	110

Table 3b. L375 furan additions to enclosures.

CHEMICAL	QUANTITY
^{3}H-2,3,7,8 TCBF	10 ug
1,2,3,7 TCBF	250 ug
1,2,3,4,8 TCBF	250 ug
2,8 DCDF	250 ug
OCDF	250 ug
1,2,3,6,8,9 HCDF	40 ug

Above mixture added to each of 4 lake enclosures.

Table 4. L114 sulfuric acid addition.

Year	Date	Litres added	Kg H_2SO_4 added	Kg H^+ added	Time-weighted mean epilimnion pH
1979	Jul 23 - Oct 15 (4 additions)	134.4	226.94	4.67	5.82
1980	Jul 13 - Sep 29 (7 additions)	235.2	397.15	8.18	6.11
1981	May 11 - Sep 28 (6 additions)	201.6	340.41	7.01	6.05
1982	May 17 - Oct 04 (6 additions)	201.6	340.41	7.01	5.90
1983	May 17 - Oct 04 (6 additions)	201.6	340.41	7.01	5.94
1984	May 31 - Sep 27 (5 additions)	168.0	283.68	5.84	5.65
1985	May 24 - Oct 10 (6 additions)	201.6	340.41	7.01	5.88
1986	May 28 - Oct 02 (6 additions)	201.6*	344.78	7.10	6.26
1987	Apr - Sep 06 (Leakage)	90.0*	153.92	3.17	
Total Additions		1635.6	2768.11	57.00	

* Denotes change to a different type of sulfuric acid. Sulfuric acid used prior to 1986 had a S.G.= 1.81 while sulfuric acid used from 1986 on had a S.G.= 1.835.

Table 5. L223 sulfuric acid additions.

Year	Date	Litres added	Kg H_2SO4 added	Kg H^+ added	Target pH	Time-weighted Mean Epi pH
1976		5537.8	9350.85	192.63		6.49
1977	May 04 - Oct 17 (17 additions)	2910.6	4914.59	101.24	6.00	6.13
1978	May 08 - Oct 23 (31 additions)	3377.4	5702.96	117.48	5.75	5.93
1979	May 21 - Oct 29 (45 additions)	2816.1	4755.12	97.97	5.50	5.64
1980	May 05 - Oct 22 (35 additions)	3099.6	5233.83	107.82	5.25	5.59
1981	May 06 - Oct 22 (35 additions)	3553.2	5999.75	123.59	5.00	5.02
1982	May 05 - Oct 26 (38 additions)	3458.7	5840.18	120.31	5.00	5.09
1983	May 10 - Oct 28 (30 additions)	2230.2	3765.80	77.58	5.00	5.13
1984	May 21 - Oct 08 (14 additions)	680.4	1148.89	23.67	5.40	5.44
1985	May 13 - Nov 06 (34 additions)	3761.1	6350.80	130.83	5.40	5.53
1986	May 05 - Oct 22 (19 additions)	2360.0*	4036.12	83.14	5.40	5.45
1987	May 06 - Oct 12 (18 additions)	1860.0*	3181.01	65.53	5.40	5.42
1988	May 24 - Oct 13 (15 additions)	1160.0*	1983.86	40.87	5.80	5.81
1989	May 23 - Oct 24 (22 additions)	1795.0*	3069.85	63.24	5.80	5.81
Total Additions		38600.1	65333.71	1345.90		

* Change in suppliers of sulfuric acid. Acid used from 1986 has a S.G. = 1.835 while acid used prior to 1986 has a S.G. = 1.81.

Table 6. L302N nitric and hydrochloric acid additions.

Year	Date	Litres HNO_3 added	Kg HNO_3 added	Litres HCl added	Kg HCl added	Kg H^+ added	Time-weighted Mean Epi pH
1982	Jun 29 - Oct 05 (14 Additions)	2282.9	1981.15			31.70	6.71
1983	May 23 - Oct 24 (26 Additions)	2463.3	2137.70			34.20	6.34
1984	May 09 - Sep 25 (25 Additions)	2804.4	2433.72			38.94	6.24
1985	May 15 - Oct 09 (21 additions)	3050.4	2647.20			42.36	6.02
1986	May 06 - Oct 21 (17 additions)	3247.2	2817.99			45.09	5.98
1987	Jun 04 - Oct 27 (24 additions)			7320.0	2532.35	69.89	5.48
1988	May 23 - Oct 19 (15 additions)			2660.0	920.23	25.40	5.32
1989	MAY 15 - OCT 30 (26 additions)			3510.0	1214.28	33.04	5.04
Total Additions		13848.2	12017.79	13490.0	4666.86	321.09	

The nitric acid has a S.G.= 1.381 and the hydrochloric acid as a S.G.= 1.10.

Table 7. L302S sulfuric acid additions.

Year	Date	Litres added	Kg H_2SO_4 added	Kg H^+ added	Target pH	Time-weighted Mean Epi pH
1981						6.75
1982	Jun 29 - Oct 05 (14 additions)	1228.5	2074.38	42.73		6.25
1983	May 23 - Oct 24 (26 additions)	1107.7	1870.41	38.53	5 90	5.86
1984	May 09 - Oct 08 (24 additions)	1152.9	1946.73	40.10	5.50	5.60
1985	May 14 - Oct 08 (21 additions)	1247.4	2106.30	43.39	5.30	5.31
1986	May 06 - Oct 21 (18 additions)	1272.3*	2175.91	44.82	5.00	5.02
1987	May 05 - Oct 28 (19 additions)	1450.0*	2479.82	51.08	4.75	4.80
1988	May 09 - Oct 19 (29 additions)	2020.0*	3454.64	71.17	4.50	4.58
1989	MAY 15 - OCT 30 (23 additions)	1220.0*	2088.48	43.02	4.50	4.53
Total Additions		10698.8	16108.19	331.82		

* Change in suppliers of sulfuric acid. Acid used from 1986 had a S.G. = 1.835. Acid used prior to 1986 had a S.G. = 1.81.

Appendix 1a. Daily L223 pH measurements and sulfuric acid additions.

	MAY								JUNE							
	1986		1987		1988		1989		1986		1987		1988		1989	
	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H2SO4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg
1											5.33				5.72	
2									5.62							
3					5.69				5.50	102.6						
4			5.93						5.59							
5	5.96	478.9	5.94							102.6					5.86	
6	5.76			34.2	5.50								5.87			136.8
7		513.1	5.81											68.4		
8	5.61			34.2							5.46		5.65		5.97	
9		376.3							5.51			68.4				
10									5.52							
11			5.81						5.53		5.47					
12	5.60		5.79		5.80				5.58						5.84	
13				68.4									5.86		5.80	85.5
14		427.6	5.03													
15							5.71								5.82	
16					5.80		5.83		5.59		5.67			68.4		
17									5.67	119.7			5.72			
18			5.13													
19	5.19		5.16						5.26						5.90	
20	5.26												5.67		5.72	85.5
21													5.87			5.85
22	5.30										5.46					
23					5.90		6.04	171.0	5.53	102.6	5.48					
24						256.5			5.52				5.81			
25			5.35				5.92		5.46							
26	5.40							171.0				85.5			5.97	136.8
27	5.41				5.79								5.80		5.74	
28													5.89	68.4		
29							5.90				5.45				5.86	
30							5.90	171.0	5.64	136.8	5.48	136.8				
31																

Appendix 1b. Daily L223 pH measurements and sulfuric acid additions.

Date	JULY								AUGUST							
	1986		1987		1988		1989		1986		1987		1988		1989	
	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg
1													5.85		5.64	
2	5.41												5.84	51.3		
3											5.46					
4					5.76		5.93	136.8	5.36			85.5				
5					5.74						5.41					
6				205.2			5.72		5.37							
7	5.55		4.96		5.78											
8		102.6											5.84		5.89	68.4
9	5.77		5.22					68.4						85.5	5.72	
10	5.85	171.0					5.84				5.42	85.5	5.73			
11	5.25				5.75		5.74		5.71							
12					5.96		5.83			85.5						
13									5.44							
14			5.35		5.94										5.70	
15	5.34		5.40			102.6							5.91			
16																
17							5.99				5.38				5.77	
18					5.99			256.5	5.43		5.38					
19							5.42									
20			5.39		5.75		5.52									
21	5.42		5.39		5.93	205.2									5.73	
22			5.39										5.75		5.77	
23			5.42													
24	5.32						5.79				5.68	171.0			5.75	
25					5.71		5.77		5.52							
26					5.74				5.65							
27			5.44		5.72		5.84			171.0						
28	5.37								5.42		5.55				5.78	
29	5.35		5.42										5.71			
30			5.41										5.80		5.69	
31							6.01	171.0								

Appendix 1c. Daily L223 pH measurements and sulfuric acid additions.

Date	SEPTEMBER								OCTOBER							
	1986		1987		1988		1989		1986		1987		1988		1989	
	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg
1	5.48		5.60	136.8												
2											5.47					
3			5.37												5.85	
4													5.87			102.6
5	5.44				5.86		5.91	68.4								
6							5.80				5.63		6.03	102.6	5.96	
7			5.56	119.7			5.80		5.66	205.2		102.6	5.78		6.00	171.0
8	5.52										5.47	68.4				
9	5.48															
10				85.5					5.59							
11							5.88						6.01		5.86	179.6
12					5.92		5.91	102.6						171.0	5.90	
13					6.04	256.5	5.88				5.49	136.8	6.02			171.0
14			5.46		5.73		5.88	171.0	5.67	136.8	5.50			171.0	5.80	
15	5.60		5.47		5.92											
16						102.6			5.58							
17				102.6							5.59				5.89	
18															5.83	
019					5.73		5.90						5.76		5.72	171.0
20								171.0			5.51					
21			5.53		5.73		5.65		5.64	273.6			5.75			
22	5.64		5.58						5.43							
23	5.71		5.48	171.0						51.3						
24		205.2	5.43						5.48						5.83	
25	5.69						5.79						6.01			
26							5.77									102.6
27					5.87	102.6							6.09			
28			5.50		5.84		5.80		5.48							
29	5.53		5.43								5.55					
30	5.28	273.6							5.50							
31															5.81	

Appendix 2a. Daily L302S pH measurements and sulfuric acid additions.

Date	MAY								JUNE							
	1986		1987		1988		1989		1986		1987		1988		1989	
	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg
1															4.50	
2									5.00		4.67					
3					5.47				4.92							
4									5.09							
5			5.85	342.0	5.67				5.04		4.78					
6	5.95	330.8											4.58		4.55	68.4
7	5.40		5.37										4.59	102.6	4.54	
8	5.54	342.0		342.0									4.45		4.58	171.0
9				256.5							4.77	102.6				
10					5.24		5.01		5.06		4.75					
11									5.03							
12			4.91	171.0		324.9										
13	5.10				4.84	205.2							4.50		4.50	
14		100.7	4.80								4.50				4.51	
15	4.91						5.01	171.0			4.73		4.48	34.2	4.54	
16					4.63		4.57		5.18		4.58					
17						171.0			5.14	68.4			4.49			
18			4.81		4.48				5.09						4.55	68.4
19	4.97		4.75							102.6					4.50	
20									4.97						4.54	
21			4.83										4.53		4.52	
22	5.08												4.50		4.54	
23					4.56	68.4					4.80		4.51			
24					4.45		4.79	171.0	4.93		4.76		4.52			
25					4.48										4.55	85.5
26	5.04		4.82						4.98						4.52	
27														34.2	4.47	
28				85.5									4.54			
29							4.69				4.91		4.54			
30					4.48			171.0	5.07		4.81	102.6	4.62			
31					4.52		4.54									

Appendix 2b. Daily L302S pH measurements and sulfuric acid additions.

Date	JULY								AUGUST							
	1986		1987		1988		1989		1986		1987		1988		1989	
	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg
1	4.99		4.70												4.47	
2	5.06	102.6											4.59	51.3		
3											4.77		4.50			
4					4.60		4.48		5.09		4.82		4.59			
5					4.61	51.3	4.48		5.13	68.4	4.83	136.8				
6			4.96		4.57		4.45		4.88		4.72					
7	5.08	102.6	4.68	136.8	4.58				4.92							
8	5.03		4.69						4.98						4.57	68.4
9	5.03		4.71										4.58	68.4		
10	4.98						4.44				4.89				4.47	
11					4.63	51.3	4.44		5.18		4.99		4.59	85.5		
12					4.64		4.46		5.20	102.6		171.0				
13			4.87		4.61		4.44		5.09		4.77					
14	5.04		4.88		4.67				4.92						4.44	
15	5.10		4.78			171.0							4.55		4.44	
16		102.6	4.81										4.59	102.6		
17	4.92		4.83				4.44				4.83				4.44	
18					4.61	171.0	4.44		4.95		4.80				4.46	
19					4.52		4.44		5.02							
20			4.89		4.52										4.48	
21			5.05	136.8	4.53		4.53		5.02						4.46	
22	5.01		4.76										4.74		4.50	
23								51.3							4.44	
24	4.99		4.81				4.55				4.76		4.58	85.5		
25							4.47	51.3	5.23		4.80	85.5	4.59			
26					4.56		4.40		5.24							
27					4.53		4.43			136.8						
28			4.86	68.4					5.20		4.75					
29	5.09	102.6	4.77										4.64	102.6	4.50	
30	4.96		4.68										4.61			
31	4.93												4.58	102.6	4.55	51.3

Appendix 2c. Daily L302S pH measurements and sulfuric acid additions.

Date	SEPTEMBER								OCTOBER							
	1986		1987		1988		1989		1986		1987		1988		1989	
	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg	pH	H_2SO_4 kg
1		34.2	4.84	85.5					4.99		4.83					
2	4.83														4.53	
3			4.75										4.63		4.53	102.6
4	4.87												4.61	85.5	4.50	
5	4.96				4.61		4.58	51.3								
6					4.62	171.0					4.93	102.6	4.59			
7			4.81						5.10	68.4	4.74					
8	5.02		4.74	102.6	4.55	102.6	4.57	68.4	4.99							
9	5.05															
10			4.71											85.5	4.50	
11							4.56						4.65	136.8	4.53	
12	5.04				4.56		4.61	102.6			4.85					85.5
13					4.59	171.0	4.57		5.09		4.86	102.6	4.55	85.5	4.51	
14					4.53		4.57	102.6		68.4						
15			4.77		4.49		4.52		4.96		4.77					
16	5.10	102.6	4.75												4.57	85.6
17													4.63		4.51	
18	5.00						4.55						4.58		4.50	
19					4.48		4.55	102.6						168.9		
20					4.50				5.19		4.80	51.3	4.53			
21										136.8	4.74					
22	5.04		4.87						4.90		4.76					
23		102.6		102.6												
24	4.78		4.76										4.50		4.50	
25							4.64	171.0							4.52	34.2
26							4.50				4.81		4.60			
27					4.60				4.97		4.81					
28					4.60					51.3						
29			4.86			102.6										
30	4.96								5.04						4.52	51.3
31															4.49	

Appendix 3a. Daily L302N pH measurements and nitric/hydrochloric additions.

Date	MAY								JUNE							
	1986		1987		1988		1989		1986		1987		1988		1989	
	pH	HNO_3 kg	pH	HCl kg	pH	HCl kg	pH	HCl kg	pH	HNO_3 kg	pH	HCl kg	pH	HCl kg	pH	HCl kg
1																
2															4.89	
3					5.23				6.12		6.72					
4									6.08							
5			6.34						6.20			200.7				
6	6.18	427.0			5.23				6.15							
7	5.59		6.42								6.08		5.34		5.00	34.6
8	5.76	427.0											5.34		4.97	
9													5.29		5.06	69.2
10					5.29		5.33				6.46	207.0				
11									6.15							
12			6.69						6.04			69.2				
13	5.36				5.30						5.57					
14		128.1	6.63										5.44		4.95	
15	5.20						5.40	103.8					5.43	55.4	4.97	
16					5.37		4.82				5.72		5.30		4.96	
17									6.14		5.67	69.2				
18					5.43				6.16	85.5			5.20			
19	5.44		6.57						5.92			69.2				
20										85.5					5.00	
21			6.45						5.77						5.01	
22	5.76												5.35			
23					5.80	207.6							5.34		5.03	
24					4.86		5.20	69.2	6.14		5.43		5.34		5.06	
25					4.88						5.54		5.30			
26	6.15		6.45													
27			6.65						6.14			103.8			5.06	
28														83.0	5.02	
29													5.44		5.00	
30							5.14				5.51		5.40			
31					5.03			69.2	6.35		4.95	138.4				
					5.11		4.86									

Appendix 3b. Daily L302N pH measurements and nitric/hydrochloric additions.

Date	JULY								AUGUST							
	1986		1987		1988		1989		1986		1987		1988		1989	
	pH	HNO_3 kg	pH	HCl kg	pH	HCl kg	pH	HCl kg	pH	HNO_3 kg	pH	HCl kg	pH	HCl kg	pH	HCl kg
1	6.21		5.28										5.36	41.5	5.06	
2	6.21	128.1									5.31					
3									5.89		5.36		5.32			
4					5.44	41.5	5.06	34.6	6.40	85.4	5.48	69.2				
5					5.37		5.00		6.17		5.30					
6			5.48		5.16		4.96		6.19						5.13	
7	6.36	128.1	5.33		5.15				6.40							55.4
8	6.10		5.37										5.30		5.00	
9	6.26		5.49				4.98				5.43					
10							5.00		6.27		5.57		5.35			
11	6.36				5.18		5.02		6.36	128.1		69.2				
12					5.18		5.03		6.08		5.32				4.99	
13			5.74		5.16											
14	6.23		5.82	138.4	5.18								5.45		5.03	
15	6.45		5.13										5.61	41.5	5.06	
16		128.1	5.21				5.14				5.54		5.28			
17	5.97		5.28		5.32		5.06	41.5	6.23		5.53				5.20	
18					5.31		4.97		6.38						5.06	
19					5.35											
20			5.40		5.34		5.07		6.32							
21			5.74	34.6									5.58		4.96	41.5
22	6.57							27.7								
23	6.92						4.99				5.37			41.5		
24	6.34		5.34				5.12		6.35		5.68	69.2				
25							5.04		6.32							
26					5.38		5.08	27.7		170.8					5.01	
27					5.33				6.02		5.51				5.04	
28			5.56										5.40	20.8		
29	6.38	85.4	5.49	69.2									5.21			
30	6.08		5.14													27.7
31	6.50						5.04									

Appendix 3c. Daily L302N pH measurements and nitric/hydrochloric additions.

Date	SEPTEMBER								OCTOBER							
	1986		1987		1988		1989		1986		1987		1988		1989	
	pH	HNO_3 kg	pH	HCl kg	pH	HCl kg	pH	HCl kg	pH	HNO_3 kg	pH	HCl kg	pH	HCl kg	pH	HCl kg
1		213.5	5.64	83.0												
2	5.73								5.98		5.43					
3			5.57												5.08	
4	5.71												5.49		5.07	41.5
5	5.89				5.41		5.06	27.7					5.57	41.5	5.02	
6					5.35	20.8										
7			5.85				5.04				5.82	103.8	5.50			6.9
8	5.87		6.01	103.8	5.31			41.5	5.98	85.4	5.74					
9	6.09								5.92			103.8				
10			5.49													
11							4.99							41.5		
12	6.24				5.32		5.01						5.60	83.0	5.18	
13					5.48		5.06				5.82					83.0
14					5.32			41.5	6.08		5.77	138.4	5.48	62.3	5.05	
15	6.08		5.74		5.35		4.97		6.01	85.4	5.69					
16	6.00	128.1	5.79									138.4			5.23	
17				103.8					6.17							
18	5.94						5.04						5.44		5.17	103.8
19					5.37		5.09	41.5					5.50		5.07	
20					5.32									138.4		86.5
21											5.53	69.2	5.22			
22	6.12		5.50							170.8	5.49					
23		128.1		103.8					6.04		5.37					
24			5.26													
25							5.05	41.5					5.30		5.01	
26							5.04								5.02	
27					5.50			41.5			5.42		5.40			
28					5.38				6.10		5.38	138.4				
29			5.47			27.7					5.12					
30	5.91								6.15						5.01	20.8
31															4.96	